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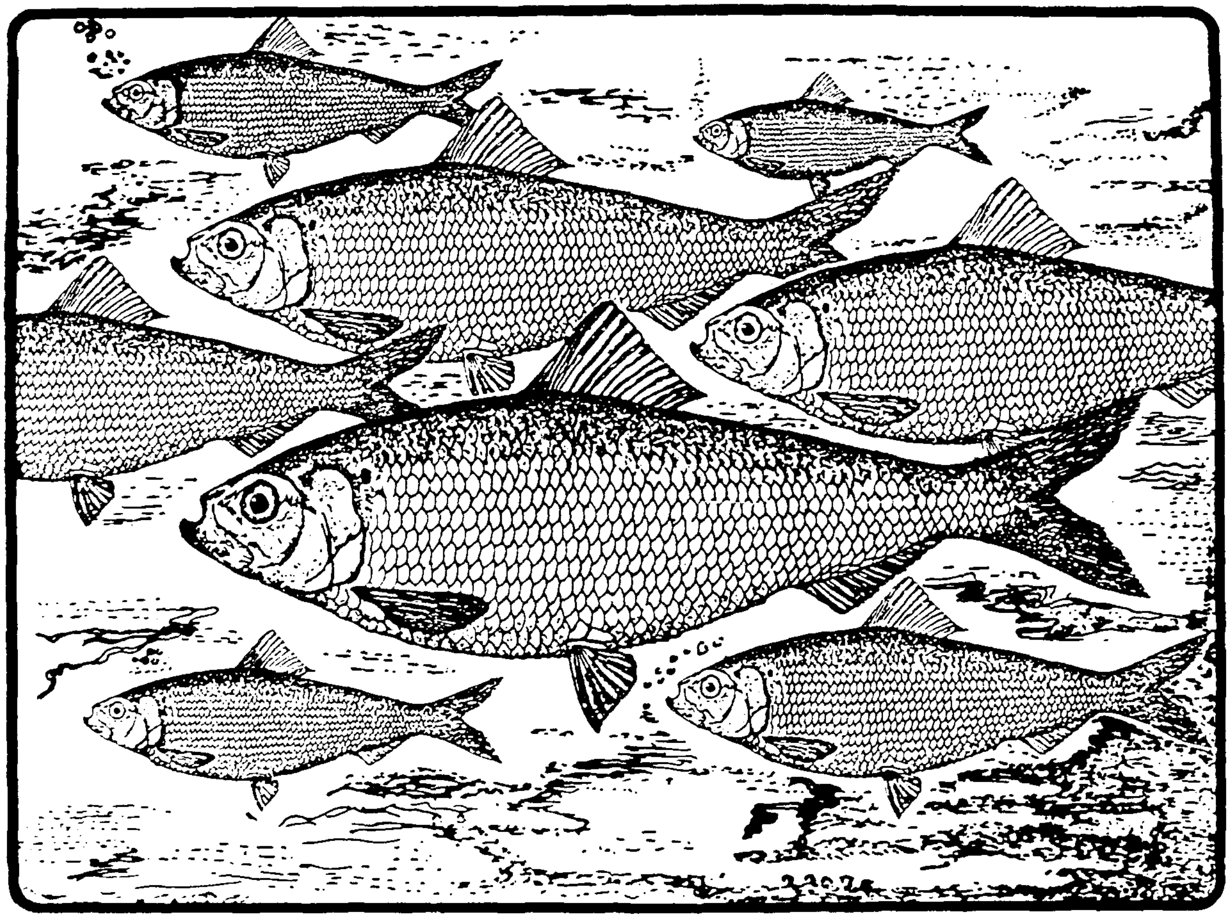
ALEWIFE AND BLUEBACK HERRING



Fish and Wildlife Service
U.S. Department of the Interior

Coastal Ecology Group
Waterways Experiment Station
U.S. Army Corps of Engineers

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Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (South Atlantic)

ALEWIFE AND BLUEBACK HERRING

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PREFACE

This species profile is one of a series on coastal aquatic organisms, principally fish, of sport, commercial, or ecological importance. The profiles are designed to provide coastal managers, engineers, and biologists with a brief comprehensive sketch of the biological characteristics and environmental requirements of the species and to describe how populations of the species may be expected to react to environmental changes caused by coastal development. Each profile has sections on taxonomy, life history, ecological role, environmental requirements, and economic importance, if applicable. A three-ring binder is used for this series so that new profiles can be added as they are prepared. This project is jointly planned and financed by the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service.

Suggestions or questions regarding this report should be directed to one of the following addresses.

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U.S. Army Engineer Waterways Experiment Station
Attention: WESER-C
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CONVERSION TABLE

Metric to U.S. Customary

Multiply	By	To Obtain
millimeters (mm)	0.03937	inches
centimeters (cm)	0.3937	inches
meters (m)	3.281	feet
meters (m)	0.5468	fathoms
kilometers (km)	0.6214	statute miles
kilometers (km)	0.5396	nautical miles
square meters (m^2)	10.76	square feet
square kilometers (km^2)	0.3861	square miles
hectares (ha)	2.471	acres
liters (l)	0.2642	gallons
cubic meters (m^3)	35.31	cubic feet
cubic meters (m^3)	0.0008110	acre-feet
milligrams (mg)	0.00003527	ounces
grams (g)	0.03527	ounces
kilograms (kg)	2.205	pounds
metric tons (t)	2205.0	pounds
metric tons (t)	1.102	short tons
kilocalories (kcal)	3.968	British thermal units
Celsius degrees (°C)	1.8(°C) + 32	Fahrenheit degrees

U.S. Customary to Metric

Multiply	By	To Obtain
inches	25.40	millimeters
inches	2.54	centimeters
feet (ft)	0.3048	meters
fathoms	1.829	meters
statute miles (mi)	1.609	kilometers
nautical miles (nmi)	1.852	kilometers
square feet (ft^2)	0.0929	square meters
square miles (mi^2)	2.590	square kilometers
acres	0.4047	hectares
gallons (gal)	3.785	liters
cubic feet (ft^3)	0.02831	cubic meters
acre-feet	1233.0	cubic meters
ounces (oz)	28350.0	milligrams
ounces (oz)	28.35	grams
pounds (lb)	0.4536	kilograms
pounds (lb)	0.00045	metric tons
short tons (ton)	0.9072	metric tons
British thermal units (Btu)	0.2520	kilocalories
Fahrenheit degrees (°F)	0.5556 (°F - 32)	Celsius degrees

CONTENTS

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We thank Richard Christie of the Dennis Wildlife Research Center, Bonneau, South Carolina, and Sara Winslow of the North Carolina Division of Marine Fisheries, Elizabeth City, for their reviews of this manuscript. We also appreciate Sue Anthony for typing and preliminary editing.

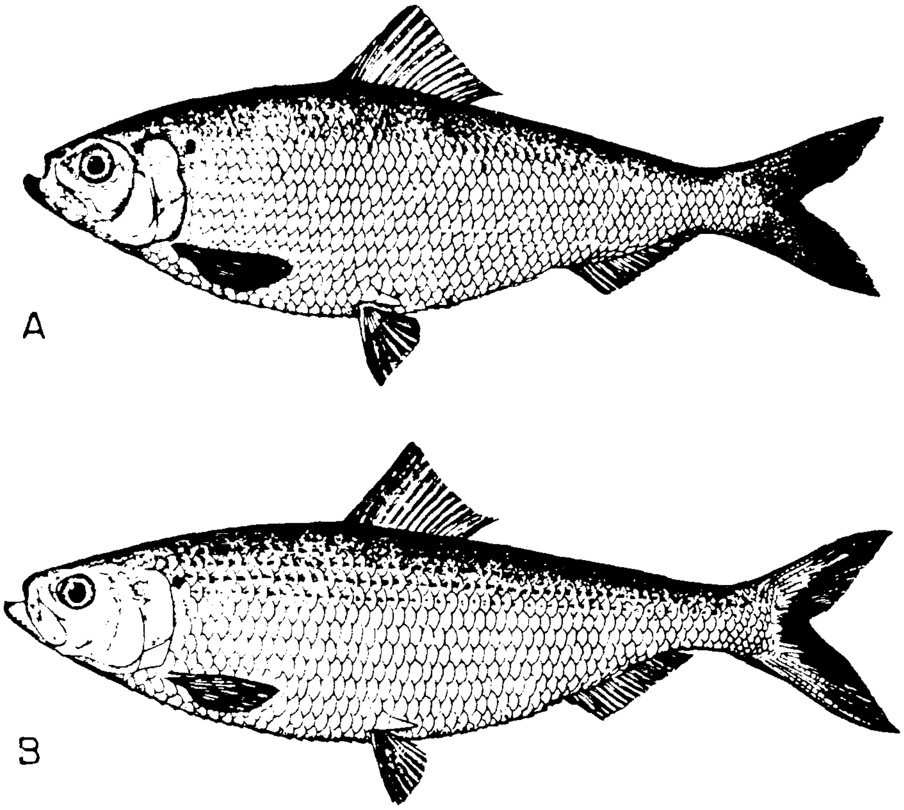

Figure 1. A. alewife; B. blueback herring.

ALEWIFE AND BLUEBACK HERRING

PROFILE SCOPE

This profile addresses life histories and environmental requirements of both alewife and blueback herring (figure 1) because the morphology, ecological role, and environmental requirements of the two species are similar. The fish are marketed together as "river herring" or "alewife," and are often combined in commercial fishing statistics. The blueback herring is plentiful throughout most of the South Atlantic Region (Cape Hatteras, North Carolina, to Cape Canaveral, Florida) and is emphasized here. The alewife is more limited in distribution in the South Atlantic Region, occurring only in waters of North Carolina and northern South Carolina. Most of the information available on alewife life history is from studies in the Middle and North Atlantic Regions or from studies of landlocked populations in the Great Lakes. Inasmuch as applicability of some of these data, particularly those describing environmental requirements, to southeastern populations of the alewife is unknown, this information should be applied with caution.

NOMENCLATURE, TAXONOMY, AND RANGE

Scientific names................Alosa pseudoharengus (Wilson) and A. aestivalis (Mitchill)
Preferred common names.........Alewife and blueback herring (Figure 1).
Other common names (both species)..... river herring, glut herring, sawbelly, goggle-eye, blackbelly, summer herring, kyak, branch herring, greyback, oldwife, gaspereau.
Class....................Osteichthyes.
Order....................Clupeiformes.
Family.....................Clupeidae.

Geographic range: The alewife is an anadromous species occurring in riverine, estuarine, and Atlantic coastal waters from Newfoundland (Winters et al. 1973) to northern South Carolina (Berry 1964). Reports of the alewife in Florida waters are questionable (McLane 1955; Williams and Grey 1975). The Great Lakes and Finger Lakes contain landlocked populations of the species (Bigelow and Schroeder 1953; Scott and Crossman 1973). The blueback herring is an anadromous species occurring in riverine, estuarine, and Atlantic coastal waters from Nova Scotia (Scott and Crossman 1973) to the St. Johns River, Florida (Hildebrand 1963). Landlocked populations of blueback herring occur in coastal plain lakes and several southeastern reservoirs. The coastal distributions of the alewife and blueback herring in the South Atlantic Region are shown in Figure 2.

MORPHOLOGY AND IDENTIFICATION AIDS

The following information was taken from Jones et al. (1978).

Alewife

Dorsal rays 12-19 (usually 13-14); anal rays 15-21 (usually 17-18); lateral line scales 42-54. Prepelvic scutes (modified scales along the ventral midline) 17-21 (usually 19-20); postpelvic scutes 12-17 (usually 14-15); gill rakers on first arch 38-46. Body strongly compressed and deep. Mouth oblique; anterior end of lower jaw thick, heavy, and extending to middle of orbit. Eye large, diameter greater than snout length. Color dorsally gray to gray-green; laterally silver with prominent dark shoulder spot; fins pale yellow to green.

Blueback Herring

Dorsal rays 15-20; anal rays 15-21; lateral line scales 46-54. Prepelvic scutes 18-21; postpelvic scutes 12-16; gill rakers on first arch 41-52. Body moderately compressed and elongate; eye diameter small, equal to or less than snout length. Upper jaw with definitive median notch; no teeth on premaxillaries. Color dorsally blue to blue-green; laterally silver with prominent dark shoulder spot; fins pale yellow to green.

Aids for Species Separation

Eggs. Unfertilized alewife eggs are green, and blueback herring eggs are amber. Oil droplets of fertilized eggs are numerous and uniformly tiny in the alewife but are of unequal size and scattered in the blueback herring (Kuntz and Radcliffe 1917; Norden 1968).

Larvae. The number of myomeres between anal vent and insertion of dorsal fin is 7-9 (mean 8.0) in the alewife and 11-13 (mean 11.8) in the blueback herring (Chambers et al. 1976).

Adults. Adults can be distinguished externally by individual scale

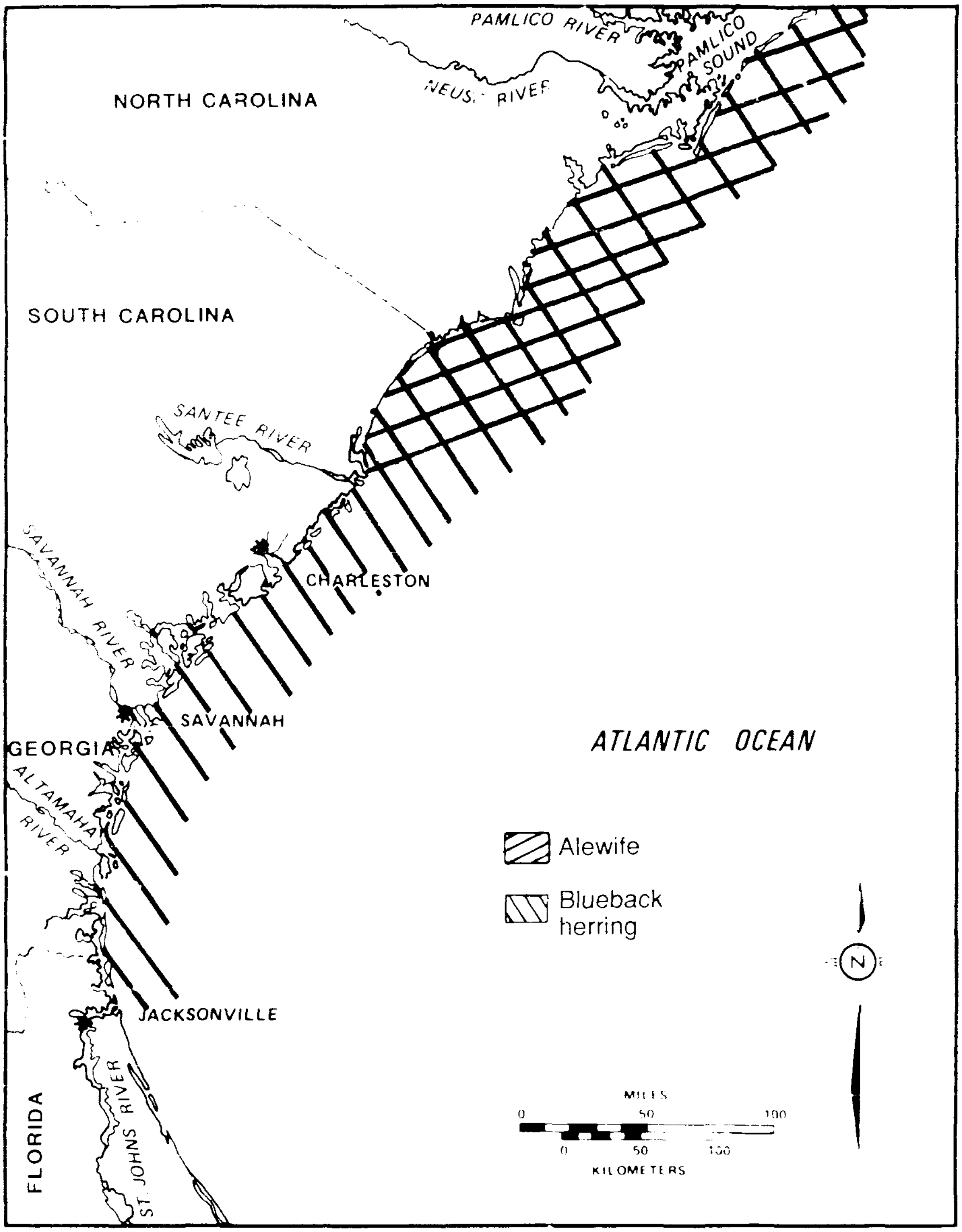

Figure 2. Coastal distributions of alewife and blucback herring in the South Atlantic Region.

markings. Scales come together on the dividing line on alewife but not on blueback herring (O'Neill 1980; MacLellan et al. 1981). Although dorsal coloration has been cited as [illegible]-distinctive in fresh specimens (Bigelow and Schroeder 1953), MacLellan et al. (1981) found no detectable difference and observed that dorsal coloration appeared to vary with light conditions. Internally, the peritoneal lining is pale, gray, or silvery with dark punctuations in the alewife and uniformly dark in the blueback herring (Leim and Scott 1966; Scott and Crossman 1973). The shapes of the otoliths are distinctive (Scott and Crossman 1973; Price 1978; O'Neill 1980).

REASON FOR INCLUSION IN SERIES

Both the alewife and blueback herring have declined in commercial importance in the South Atlantic Region over the past 15 years (Rulifson et al. 1982). They are ecologically important species due to their trophic level. Both species are planktivorous and are important links between zooplankton and piscivores in freshwater and marine food webs.

LIFE HISTORY

Spawning

Alewives and blueback herring spawn from late winter to early summer in the South Atlantic Region. Marshall (1977) and Sholar (1975) reported spawning runs of alewives from mid-March to late May in the Neuse River, North Carolina. Blueback herring spawn in the St. Johns River, Florida, from January to early May (Williams et al. 1975). Blueback herring spawning runs occur later in the season with increasing latitude, and continue into June in North Carolina rivers (Street 1970; Sholar 1975; Sholar 1977; Bulak and Curtis 1978; Hawkins 1979; Fisher 1980).

Spawning temperature requirements for either species are poorly defined because spawning runs often coincide and most spawning temperatures have been recorded for "river herring" rather than for each species separately. Marshall (1977), however, reported ripe alewives at temperatures of 15-20 °C in the Neuse River, North Carolina. Spawning activity of blueback herring has been observed at temperatures as low as 13 °C in the Neuse River, North Carolina (Hawkins 1979). Spawning activity peaks at 17-19 °C in North Carolina and South Carolina (Sholar 1977; Bulak and Curtis 1978) and at 17-20 °C in Georgia and northern Florida (Street 1970; Williams et al. 1975). Both species cease spawning when temperatures exceed 27 °C (Hawkins 1979).

Although a variety of spawning habitats are used by both species, blueback herring prefer shallow areas covered with vegetation (Frankensteen 1976), old ricefields (Christie 1978), and river swamps and small tributaries above tidal influence (Godwin and Adams 1969; Street 1970). Brackish and tidal areas are rarely used by blueback herring for spawning (Loesch and Lund 1977). In contrast, alewives have been reported spawning in barrier beach ponds (Bigelow and Welsh 1925) and brackish streams (Kissil 1974), as well as at upstream, mid-river sites (Bigelow and Schroeder 1953); they spawn over a detritus-covered bottom with attached vegetation, sticks, or other organic matter and occasionally over a hard sand bottom (Cooper 1961). Spawning in both species occurs diurnally and nocturnally, although most activity is nocturnal (Graham 1956; Edsall 1964). Blueback herring make repeat spawning runs and return to the same river to spawn. Thus, racial differences may exist between rivers and management of the fishery may need to be on a river-by-river basis (Christie 1984).

Eggs

Fecundity estimates of blueback herring in the Altamaha River, Georgia, were 120,000-400,000 eggs per female, and averaged 244,000 (Street 1970). Williams et al. (1975) estimated that blueback herring in the St. Johns River, Florida, contained 150,000-349,000 eggs (mean, 262,000). There are no reported fecundity estimates for alewife in the South Atlantic Region. Smith (1907) reported that alewives in the Potomac River, Virginia, contained an average of 102,800 eggs per female, and Kissil (1969) estimated that alewives in Connecticut rivers produced 229,000 eggs per female.

Until water-hardened, eggs of both species are adhesive and will sink unless buoyed by river or tidal currents. Within 24 h after spawning, the eggs lose their adhesive property (Loesch and Lund 1977; Jones et al. 1978). Fertilized blueback eggs are yellowish and have scattered, unequal-sized oil droplets, whereas alewife eggs are amber and have numerous small oil droplets (Kuntz and Radcliffe 1917; Norden 1968). Egg diameters are 0.80-1.27 mm in the alewife and 0.87-1.11 mm in the blueback herring (Mansueti 1956; Norden 1968). Incubation times for blueback herring eggs are 80-94 h at 20-21 °C and 55-58 h at 22-24 °C (Cianci 1969; Morgan and Prince 1976). Comparative incubation times for alewife eggs are 89 h at 21.1 °C (Edsall 1970) and 72 h at 23.8 °C (Kellogg 1982).

Larvae

Yolk-sac larvae of both species are 2.5-5.0 mm total length (TL) at hatching and average 5.0 mm TL at yolk-sac absorption (Mansueti 1956; Norden 1968). This stage lasts 2-5 days in the alewife and 2-3 days in the blueback herring (Mansueti 1956; Cianci 1969; Jones et al. 1978).

The larval stage (from yolk-sac absorption to transformation into the juvenile stage) lasts 2-3 weeks in both species. Larval alewives are 4.3-19.9 mm standard length (SL), and larval blueback herring are 4.0-15.9 mm SL (Cooper 1961; Jones et al. 1978). Jones et al. (1978) presented detailed drawings of the developmental stages of eggs, yolk-sac larvae, and advanced larvae of both species.

Juveniles

Transformation to the juvenile stage is completed in both species at about 20 mm TL. Scales first appear when juveniles are 25-29 mm TL and are fully developed at 45 mm TL (Hildebrand 1963; Norden 1968).

Nursery areas for juvenile blueback herring in the Neuse River, North Carolina, are characterized by deep, black water draining hardwood swamps, with little salinity or current and with a mud or detritus bottom (Marshall 1977). Juvenile alewife and blueback herring were present in South Creek estuary, North Carolina, in spring (Rulifson 1985). In the South Atlantic Region, juvenile blueback herring remain in primary nursery areas until October and then begin migrating to shallow, high-salinity estuaries for overwintering. These secondary nurseries are used until yearlings migrate to sea in the spring (Spitsbergen and Wolff 1974).

Primary nursery areas for alewives are the lower reaches of rivers in brackish water or tidally influenced freshwater. Migration patterns of juvenile alewives are not as clearly defined as those of blueback herring. The fish migrated from primary nursery areas in November in the Cape Fear River, North Carolina (Sholar 1977), but juveniles of 24-105 mm TL were captured in freshwater Lake Mattamuskeet, North Carolina, during June, November, and January, even though access to coastal areas was maintained at all times (Tyus 197[illegible]).

Juvenile alewives use high-salinity estuaries as secondary nurseries before migrating to sea in winter and early spring (Holland and Yelverton 1973).

Adults

Blueback herring and alewives reach sexual maturity by age III or IV (Loesch 1969) at about 250 mm TL (Johnson et al. 1978). Females of both species are larger than males of the same age (Williams et al. 1975; Sholar 1977). Blueback herring sex ratios (male:female) in North Carolina ranged from 1:2.80 in the Northeast Cape Fear River (Fischer 1980) to 1:0.65 in the Neuse River (Marshall 1977). Corresponding ranges of sex ratios for the alewife were from 1:3.0 in the Cape Fear River (Fischer 1980) to 1:0.45 in the Northeast Cape Fear River (Sholar 1977). In offshore North Carolina waters, male blueback herring were only slightly outnumbered by females, 1:1.02 (Johnson et al. 1978).

After spawning, adults of both species return to the ocean, where they inhabit a narrow band of coastal water close to natal estuaries (Jones et al. 1978). Distribution of parental stocks during winter is not well defined, but they are presumed to overwinter in offshore waters up to 145 m deep (Bigelow and Schroeder 1953; Hildebrand 1963).

GROWTH CHARACTERISTICS

Growth Rates

No published data exist on growth rates of juvenile alewives or blueback herring in the South Atlantic Region, but some information is available based on average sizes of juveniles at different times of the year in various rivers. Juvenile blueback herring in the Cape Fear River, North Carolina, grew from 49.3 mm fork length (FL) in July to a mean of 57.4 mm FL in November (Davis and Cheek 1966). Mean fork lengths of juveniles in the Altamaha River, Georgia, increased from 34.8 mm FL in July to 60.6 mm FL in November, or a 25.8 mm increase over four months (Godwin and Adams 1969). Juvenile alewife in the Neuse River, North Carolina, increased from 35 mm FL in June to 75 mm FL in November (Hawkins 1979), whereas juveniles in the White Oak, Cape Fear, and Northeast Cape Fear Rivers, North Carolina, increased from 47 mm FL in July to 81 mm FL in December (Davis and Cheek 1966; Sholar 1975).

Holland and Yelverton (1973) estimated relations between fork length and age, and fork length and weight for alewives and blueback herring from the Chowan River and offshore North Carolina (Table 1). Adult blueback herring and alewives attain a maximum size of about 290 mm FL (females) and 270 mm FL (males) by age VII or VIII (Holland and Yelverton 1973). The oldest reported blueback herring and alewives (age IX) from the South Atlantic Region were collected in Albemarle Sound (Holland et al. 1975).

THE FISHERY

Blueback herring and alewives are marketed together and labeled as "river herring" or "alewife" in many fisheries statistics. Both species are sold fresh or salted for human consumption, but most are used for fish meal and fish oil in fertilizer, pet food, and domestic animal food. Some are used for fishing bait, and some are marketed for crab and crayfish bait. Roe from these species is canned and is highly valued as food (Joseph and Davis 1965; Pate 1974; Street and Davis 1976; Merriner 1978).

U.S. commercial landings of river herring (both species combined) along the Atlantic coast were 4,949 metric tons (t) in 1980 and 3,754 t in 1981.

Table 1. Fork length (FL; in mm) - age (A; in years) and fork length-weight (W; in grams) relationships of alewife and blueback herring from the Chowan River and offshore North Carolina. Equations reported by Holland and Yelverton (1973).

Species and Sex[a]	Location	Regression equation
Alewife		
C	Offshore, NC	$W = 2.42 \times 10^{-6}\ FL^{3.34}$
C	Offshore, NC	$A = 190.50\ FL^{0.18}$
M	Chowan River at Tunis, NC	$W = 7.49 \times 10^{-6}\ FL^{3.13}$
F	Chowan River at Tunis, NC	$W = 7.78 \times 10^{-6}\ FL^{3.13}$
C	Chowan River at Tunis, NC	$A = 172.70\ FL^{0.22}$
M	Chowan River at Tunis, NC	$A = 181.40\ FL^{0.18}$
F	Chowan River at Tunis, NC	$A = 177.70\ FL^{0.22}$
Blueback Herring		
C	Offshore, NC	$W = 4.51 \times 10^{-6}\ FL^{3.20}$
C	Offshore, NC	$A = 130.60\ FL^{0.37}$
M	Chowan River at Tunis, NC	$W = 9.01 \times 10^{-6}\ FL^{3.08}$
F	Chowan River at Tunis, NC	$W = 2.15 \times 10^{-5}\ FL^{2.92}$
C	Chowan River at Tunis, NC	$A = 198.40\ FL^{0.11}$
M	Chowan River at Tunis, NC	$A = 197.90\ FL^{0.10}$
F	Chowan River at Tunis, NC	$A = 200.90\ FL^{0.12}$

[a]C = sexes combined; M = males; F = females

These landings were worth $779,000 and $671,000, respectively (NMFS 1982). The largest river herring fishery in the South Atlantic Region is in North Carolina. From 1972 to 1981, North Carolina river herring landings (31,357 t) accounted for over 97% of the total for the South Atlantic Region and were worth about $3 million (Pulifson et al. 1982). North Carolina river herring landings in 1985 were 11,548 thousand pounds, the highest since 1972 when the catch was 11,237 thousand pounds (Winslow et al. 1985)

Fishing effort for both species is concentrated in rivers during spring spawning runs. In North Carolina, they are exploited by anchor gill nets, drift gill nets, haul seines, and pound nets (Pate 1974). Pound nets recently produced about 95% of the yearly catch (McCoy 1976). In South Carolina, the principal commercial gears used are haul seines and dip nets (Bulak et al. 1979); in Florida, haul seines and occasionally pound nets are used (Williams et al. 1975). There is no commercial exploitation of blueback herring in Georgia, although some of the fish are caught incidentally by fishermen seeking American shad, *A. sapidissima*, and hickory shad, *A. mediocris* (Rulifson et al. 1982).

Alewife and blueback herring populations appear to be declining in the South Atlantic Region. Commercial landings in North Carolina have decreased since 1969, and Florida landings are no longer reported. In 1975, South Carolina imposed a quota on commercial landings in an effort to reverse population declines in the Cooper River and Lake Moultrie (Curtis 1976). Several factors seem to be causing this general decline. Alewives and blueback herring do not reach reproductive maturity until age III or IV and, unlike American shad that die after spawning once, these two species rely on repeat spawners to maintain their population levels. The inshore fishery is based on the exploitation of sexually mature adults; overfishing decreases the abundance of older individuals, thus decreasing annual spawning potential (Pate 1974). The offshore North Carolina fishery was established in 1967 as a trawl fishery that exploits sexually immature alewives and blueback herring (NMFS 1982). The combined effect of the two fisheries has apparently played an important role in the decline of the North Carolina populations (Rulifson et al. 1982).

The status of blueback herring and alewife fisheries in North Carolina and recommendations for management were summarized by Loesch et al. (1977), Johnson et al. (1978), Rulifson et al. (1982), and Winslow et al. (1985)

ECOLOGICAL ROLE

Food

The alewife and blueback herring are primarily zooplanktivores, but fish eggs, crustacean eggs, insects and insect eggs, and small fishes may be important food for the larger fish (Bigelow and Schroeder 1953). Larvae begin feeding on zooplankton immediately after the formation of a functional mouth (about 6 mm TL). They first rely on small cladocerans and copepods and begin to feed on larger zooplankton species as their mouths can accommodate them (Norden 1968; Nigro and Ney 1982). Davis and Cheek (1966), who compared the food of juvenile alewife and blueback herring in the Cape Fear River, North Carolina, reported that blueback herring selected copepods and dipteran larvae more frequently than did alewives, whereas alewives consumed more ostracods, insect eggs, and insect parts. The amounts of crustacean eggs in the diets were similar for both species. No benthic organisms or detritus were found in the stomach contents of either species.

The stomachs of all adult blueback herring captured in offshore North Carolina and examined for food contained amphipods, copepods, isopods, cumaceans, mysids, and decapod larvae; none contained fish or fish remains (Holland and Yelverton 1973). Alewife stomachs examined in the same study contained unidentified fish remains in addition to zooplankton. After spawning in freshwater, adult alewives feed principally on the caddis fly *Brachycentrus* sp (Cooper 1961).

Alewives feed three ways. Two are size-selective (in favor of larger prey): 1) particulate feeding on individual prey; and 2) gulping, in which the mouth opens and closes more slowly than in particulate feeding. The third method is filtering with the mouth held agape. The feeding method used depends on an interaction of fish size with prey size, type, and density (Janssen 1976).

Competitors

Few studies have been conducted on competitive interactions of alewife and blueback herring. Some competition for food may occur between the two species due to similarities in diet and feeding behavior. Loesch et al. (1982a) described a spatial separation between young alewives and blueback herring in the same habitat, which may lead to reduced competition for food.

Predators

Alewives and blueback herring are prey for many riverine, estuarine, and marine piscivores (Cooper 1961), including gulls and terns (Laridae), green herons (Butorides virescens), otter (Lutra canadensis), and mink (Mustela vison). Reported fish predators on juvenile alewives and blueback herring include American eel, Anguilla rostrata, and white perch, Morone americana (Kissil 1969), and chain pickerel, Esox niger, largemouth bass, Micropterus salmoides, yellow perch, Perca flavescens, and pumpkinseed, Lepomis gibbosus (Cooper 1961). Predators on adults are bluefish, Pomatomus saltatrix, weakfish, Cynoscion regalis and striped bass Morone saxatilis (Cooper 1961; Tyus 1972). Blueback herring play an important ecological role in the Santee-Cooper System, South Carolina. Since 1975, an average of 5.3 million herring pass upstream annually through the Pinopolis Navigation Lock. These fish help to maintain an important striped bass sport fishery in Lakes Marion and Moultrie (Bulak and Curtis 1978).

Effects on Freshwater Ecosystems

Spawning alewives contribute a substantial net increase in carbon, nitrogen, and phosphorus to small streams. Most of the input comes from mortality of the fish. Increased nutrients from alewives lead to faster microbial decomposition of leaf litter, and probably benefit invertebrates that feed on decaying litter. These invertebrates are important prey of fishes (Durbin et al. 1979).

ENVIRONMENTAL REQUIREMENTS

Temperature

Hatching success of blueback herring eggs exposed to simulated power plant thermal regimes (7-20 °C above ambient) was 10%-14% below that of control eggs (Schubel and Auld 1973). The hatching success of blueback herring and alewife eggs was not significantly affected by temperature increases of 6-10 °C for 2.5-60.0 min (Schubel 1974). Larvae from eggs stressed by prolonged exposure to elevated temperatures, however, showed a variety of deformities, including shortened bodies, enlarged finfolds, and curved or twisted spines. The magnitude and frequency of deformities were directly related to elevated temperature levels and time of exposure (Koo and Johnson 1978). Incubation temperatures below 10.6 °C resulted in 69% deformities in alewife larvae (Edsall 1970).

There is no information available on the effects of temperature on juvenile blueback herring. Upper lethal temperature limits and critical thermal maxima (the mean temperature at which experimental fish lose equilibrium) for juvenile alewife collected from Lake Michigan exceeded those of adults by 3 to 6 °C and increased with higher acclimation temperatures. The preferred temperature was consistently higher for juveniles than for adults (Otto et al. 1976). Some juvenile alewives survived and fed at temperatures of 34.4-35.0 °C (Dorfman and Westman 1970). For a northern alewife population, McCauley and Binkowski (1982) reported an upper incipient lethal temperature of 31-34 °C for adults. Fish were acclimated first at 27 °C.

In heat-shock tests with adult alewives from Lake Michigan, critical thermal maxima and upper lethal temperature limits increased as acclimation temperatures increased; at equal acclimation temperatures, the critical thermal maximum was not affected by fish age. In cold-shock tests with adult alewives from Lake Michigan, temperatures less than 3 °C caused 100% mortality regardless of the acclimation temperature. Some fish survived a temperature decrease of 10 °C if the lower test temperature was not below 3 °C (Otto et al. 1976). No information is available on temperature effects on adult blueback herring. **Alewife and blueback herring on the open ocean were most frequently caught at 4-7 °C (Neves 1981).**

Salinity

Although little information exists on salinity tolerances of alewives and blueback herring, they are apparently efficient osmoregulators in freshwater or saltwater and are highly tolerant of salinity changes. Chittenden (1972) observed no mortality of adult blueback herring from either gradual or abrupt salinity changes, including transfers from freshwater to seawater and the reverse. Blood and muscle electrolyte concentrations were similar in alewives held in seawater and in freshwater at the same temperature (Stanley and Colby 1971). The existence of landlocked, reproducing populations in lakes and reservoirs indicates that neither species requires a saltwater environment to complete its life cycle.

Dissolved Oxygen

Mass mortalities of juvenile blueback herring occurred in the lower 48 km of the Connecticut River during June and July in 1965-67 and 1971, when dissolved oxygen concentrations fell below 1.3 mg/L at 24.6 °C and 3.6 mg/L at 27.6 °C (Moss et al. 1976).

In laboratory studies, juvenile alewives responded to dissolved oxygen concentrations below 2.0 mg/L by moving to the surface of the test chamber. They can survive for at least 5 min at concentrations as low as 0.5 mg/L if allowed access to an area of 3.0 mg/L or higher concentration in which to recover (Dorfman and Westman 1970).

Substrate and System Features

Requirements for spawning habitat are more specialized in the blueback herring than in the alewife. Blueback herring prefer shallow, vegetated areas with slow current, whereas alewives use a variety of spawning sites, from brackish tidal water and barrier beach ponds to upstream mid-river sites. Changes in water currents or substrates in spawning rivers may affect blueback herring more than alewives because of the more specific spawning site requirements of blueback herring.

Schubel and Wang (1973) found that high levels of suspended sediment caused a delay in hatching of several hours. However, Auld and Schubel (1978) found that 100 mg/L or less of suspended sediment had no effect on the hatching success of alewife or blueback herring eggs.

Juvenile alewives and blueback herring in the Cape Fear River, North Carolina, were found in areas with 4 to 22 ppm free carbon dioxide, 5 to 32 ppm alkalinity, 2.4-10.0 mg/L dissolved oxygen, and a pH of 5.2 to 6.8 (Davis and Cheek 1966).

In pooled samples taken throughout the year, alewives on the open sea were captured most often at 56-110 m depths, and blueback herring at 27-55 m. Evidence suggests that both species are vertical migrators, following the diel movements of zooplankton in the water column (Neves 1981).

Environmental Contaminants

The LC-50 (lethal concentration for 50% of fish tested) of total residual chlorine for blueback herring eggs in the Potomac River, Maryland, ranged from 0.20 to 0.32 ppm, and all larvae exposed to sublethal concentrations of total residual chlorine were deformed (Morgan and Prince 1976). The body tissues of juvenile alewives and blueback herring from the Chickohominy and James Rivers, Virginia, contained kepone concentrations greate than 0.3 ppm -- the action level f possible closure of a fishery ' ohnson et al. 1978; Loesch et al.)82b). Less than 0.3 ppm kepone was present in young alewives and blueback herring from the Mattaponi and Pamunkey Rivers, Virginia, and no detectable concentration of kepone was found in fish from the Rappahannock River, Virginia, or the Potomac River, Maryland (Loesch et al. 1982b).

Status of water quality and system features of major river systems of the South Atlantic Bight are shown in Table 2.

	None or inadequate information	Channelization	Dredge and fill projects	Bulkheading	Dams and impoundments	Industrial water intakes	Inadequate fishway facilities	Poor control of water release from dams	Reduced spawning habitat	Reduced nursery habitat	Poor food availability	Spawning grounds too accessible	Industrial discharge location	Chemical pollution (1)	Thermal effluents	Turbidity	Low oxygen levels	Sewage outfalls	Reduced freshwater to estuaries	Generally poor water quality	Other (see footnote)
N. CAROLINA																					
Currituck So.	X																				
Albemarle So.																	X			X	
Chowan		X	X	X		X			X	X	X	X	X	X		X	X	X	X	X	
Roanoke		X	X		X	X		X	X	X	X	X	X	X		X	X	X		X	
Pungo	X																				
Other Albemarle area rivers																				X	
Albemarle So tributaries		X	X	X					X	X	X	X		X			X	X		X	
Tar		X			X	X		X	X	X	X	X	X	X		X	X	X		X	
Pamlico	X																				
Neuse		X			X	X	X	X	X	X	X	X	X	X		X	X	X		X	2
Trent	X																				
North	X																				
Newport	X																				
White Oak	X																				
New		X							X	X											
Cape Fear		X			X	X	X	X	X	X	X	X	X	X		X	X	X		X	2
N.E. Cape Fear		X							X	X	X	X		X		X	X	X		X	
Pee Dee					X	X		X					X	X		X	X	X		X	
S. CAROLINA																					
Waccamaw	X																				
Pee Dee					X		X		X	X											
Sampit														X						X	
Santee					X		X		X	X											
Cooper					X				X	X											
Ashley	X																				
Edisto	X																				
Ashepoo	X																				
Combahee	X																				
Lynches	X																				
Savannah					X		X		X	X										X	
GEORGIA																					
Savannah			X		X				X	X	X		X	X						X	
Ogeechee		X	X		X				X	X	X		X							X	
Altamaha		X	X		X				X	X	X		X	X						X	
Satilla		X	X		X				X	X	X		X							X	
St. Marys			X		X				X	X	X		X							X	
Apalachicola					X				X												
FLORIDA (Atlantic coast)																					
St. Marys		X		X		X				X			X	X						X	
Nassau				X		X				X			X	X						X	
St. Johns		X	X	X	X	X			X	X		X	X	X	X	X	X	X	X	X	3
Tomoka														X						X	4

1. E.g., Heavy metals, organics.
2. Locks and barriers.
3. Agricultural drainage; agricultural and domestic non-point source pollution; overfishing.
4. Agricultural and domestic non point source pollution.

Table 2. System features and water quality characteristics that may affect populations of alewife or blueback herring in the South Atlantic Bight (from Rulifson et al. 1982b).

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